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THE CINCINNATI GROUP IN WESTERN TENNESSEE, BETWEEN THE TENNESSEE RIVER AND THE CENTRAL BASIN.

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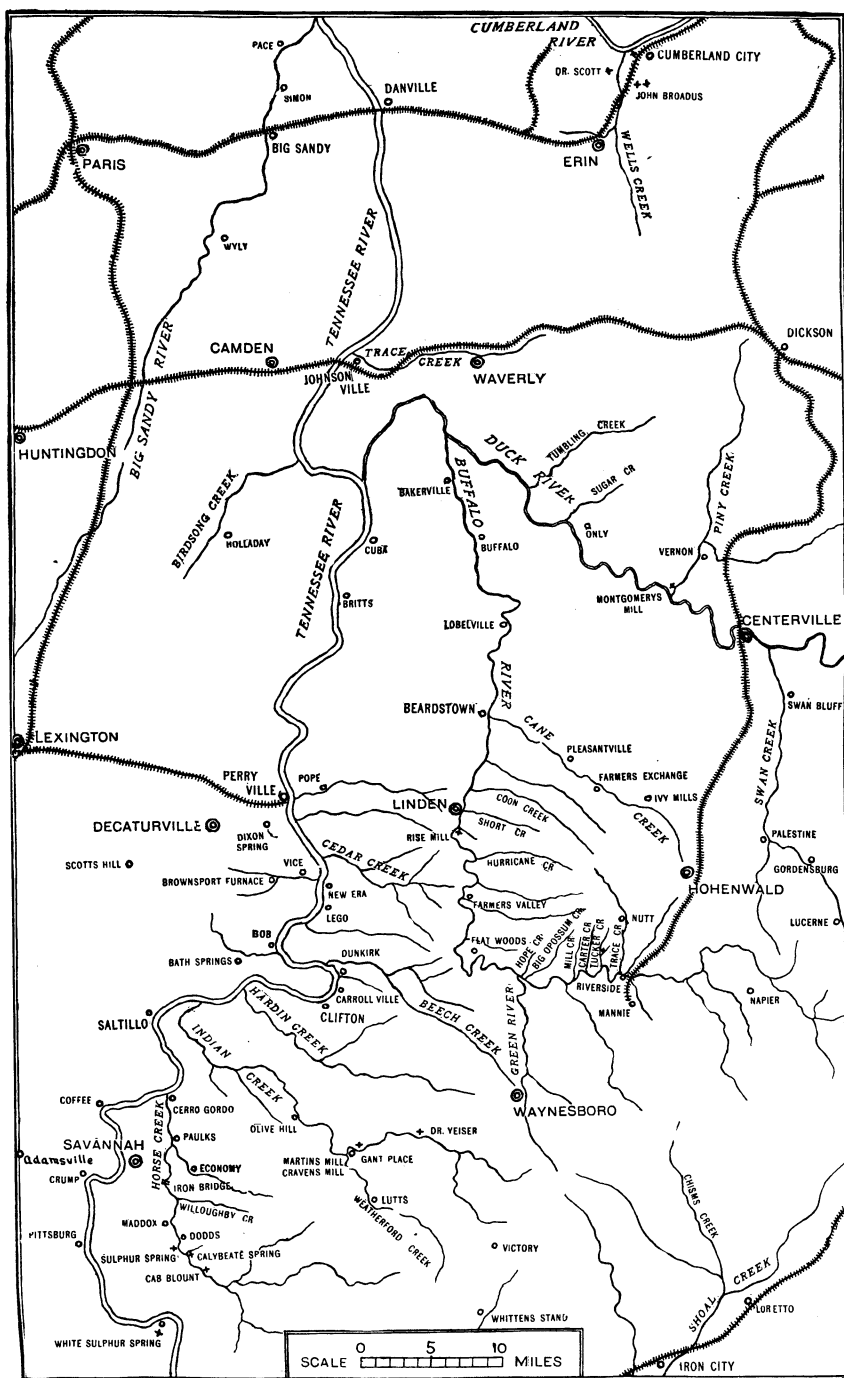
A. THE SUBDIVISIONS OF THE CINCINNATI GROUP IN OHIO.

In 1865 Meek and Worthen¹ proposed the name "Cincinnati group" for that part of the Ordovician which is exposed in Ohio.

In 1873 Professor Orton² divided the Ordovician of Ohio into three divisions. The middle division included all rocks exposed within the boundaries of the city of Cincinnati; its inferior limit was at low water of the Ohio river, its upper boundary was formed by the highest stratum found in the Cincinnati hills. This middle division was called by Professor Orton the *Cincinnati beds proper*. All rocks above the highest stratum exposed in the Cincinnati hills and below the lowermost beds of Silurian age (the Upper Silurian of the Ohio Survey and of most authors) were included in the upper division. The strata that form the summit of the Cincinnati hills are found also in the immediate vicinity of Lebanon. The base of the upper division is also well exposed here, and its fauna has been carefully studied by local collectors. Therefore the name *Lebanon beds* was given to the upper division, although the nearest outcrops of the top of the Lebanon beds are about seven miles north of Lebanon, and

¹ *Philadelphia Acad. Nat. Sci., Proc.*, Vol. XVII, p. 155.

² *Ohio Geol. Surv.*, Vol. I, pp. 370-73.



the intervening section is poorly exposed. Those Ordovician rocks of Ohio which stratigraphically belong below those exposed at low-water mark in Cincinnati were included in the lower division. The best and clearest section of these rocks is seen near Point Pleasant, about twenty-five miles above Cincinnati, on the Ohio river. Although the upper boundary of the lower division cannot be readily determined with exactness at this locality, the rocks included within this division were called the *Point Pleasant beds*.

At present the term *Cincinnati group* no longer includes all of the Ordovician rocks exposed in Ohio. Since the Point Pleasant beds and the lower fifty feet of rock at Cincinnati have been identified as equivalent to the upper part of the Trenton, the term *Cincinnati group* has been restricted so as to include only the remainder of the *Cincinnati beds proper* and the *Lebanon beds* of Orton.

In 1897 Winchell and Ulrich¹ divided the *Cincinnati beds proper* of Orton into two divisions, identifying the lower with the *Utica*² of New York, and the upper with the *Lorraine*. For the term *Lebanon beds* they substituted the term *Richmond group*, since the name *Lebanon* had been used by Professor Safford for a formation included in the Trenton group of Tennessee, before Professor Orton applied it to his upper division of the Cincinnati group. No sections are described, but at Cincinnati the Utica is said to be over 250 feet thick, and the Lorraine about 200 feet. The line between the Utica and Lorraine is sufficiently well established, to anyone acquainted with the Cincinnati section, by the statement that at the base of the Lorraine there are some arenaceous layers that on weathering frequently preserve the fossils as casts, and that above these there are numerous layers of crystalline limestone, three to ten inches in thickness, separated by relatively thin bands of shale. The line of division between the Utica and Lorraine is evidently the same as that between beds XI and XII of Ulrich.³

¹ *Minnesota Geol. and Nat. Hist. Surv., Final Rept.*, Vol. III, Part II, p. ci.

² ULRICH, "Correlation of Lower Silurian Horizons," *Am. Geol.*, Vol. I (1888), p. 315.

Ibid., Vol. II, p. 41

In 1896 Harper and Bassler¹ adopted the division of the Cincinnati group made by Winchell and Ulrich in the preceding paper, written at an earlier date but still unpublished. The Lorraine is said to be terminated above by a widely distributed bed containing rolled fragments and entire specimens of the large form of *Platystrophia lynx* in great abundance. The Richmond group comprises the overlying part of the Cincinnati group and is, therefore, the exact equivalent of the Lebanon beds of Orton.

In 1900 Nickles and Bassler² adopted the division of the Cincinnati group into the Utica, Lorraine, and Richmond. Their lists of fossil bryozoa established still more definitely the line between the Utica and the Lorraine, as identified by Ulrich. The line between the Lorraine and the Richmond is apparently still the same as that between the Cincinnati beds proper and the Lebanon beds of Professor Orton.

In 1902 J. M. Nickles³ referred the lower 80 feet of the Lebanon beds of Orton to the Lorraine, thus increasing the section to be identified as Lorraine and diminishing the section to be included in the Richmond. The strata including the thin *Dinorthis retrorsa* bed are for the first time definitely⁴ excluded from the Richmond. The base of the Richmond was placed just beneath the lowest beds containing *Strophomena rugosa* (the *Strophomena planumbona* of the Ohio Survey), *Rhynchotrema capax*, *Dalmanella jugosa* and *Streptelasma rusticum* (the *Stroptelasma corniculum* of the Ohio Survey). The Lorraine of Ohio, as extended by Nickles, was then subdivided into six sets of beds, called, in descending order: the Warren beds, 80 feet thick; Mount Auburn beds, 20 feet; Corryville beds, 60 feet; Bellevue beds, 20 feet; Fairmount beds, 80 feet; and the Mount Hope beds, 50 feet. The Warren beds include those formerly referred to the Lebanon beds by Orton, but transferred to the Lorraine by Nickles. The Mount Auburn beds include the highest strata

¹ *Catalogue of Fossils in Vicinity of Cincinnati, O.* Private publication.

² "Synopsis of American Fossil Bryozoa," *Bulletin U. S. Geol. Surv.*, No. 173.

³ "The Geology of Cincinnati," *Jour. Cincinnati Sec. Nat. Hist.*, Vol. XX, No. 2.

⁴ ULRICH, "Correlation of Lower Silurian Horizons," *Am. Geol.*, Vol. II (1888), p. 41.

exposed in the Cincinnati hills. They are also known as the *Platystrophia lynx* beds, on account of the great abundance of a characteristic variety of this fossil which attains a large size and has a short hinge line. Both the Warren and the Mount Auburn beds are well exposed north of Lebanon, O. The Fairmount beds are well exposed immediately west of the river at Hamilton.

Mr. J. M. Nickles determined the thickness of the Utica to be 260 feet at Cincinnati, and the thickness of the Lorraine at the same locality as 310 feet. The thickness of the Richmond was stated to be between 200 and 300 feet, the locality not being mentioned. At the more northern exposures in Indiana its thickness appears to be 240 feet, according to measurements by the present writer.

Judging from exposures in Nelson and Washington counties in central Kentucky, and from outcrops along the Cumberland river in southern Kentucky, the Lorraine becomes thinner southward. The rate of thinning, however, is much less than that of the Richmond in the same distance. In Marion county in central Kentucky the Richmond does not exceed 35 feet. Along Fishing creek,¹ a tributary of the Cumberland river, the Richmond is at least 27 feet thick.

B. THE CINCINNATI GROUP IN THE TENNESSEE RIVER VALLEY.

The Utica, Lorraine, and Richmond groups may be identified also in Southwestern Tennessee, along the Tennessee river and some of its tributaries.

1. *The Saltillo Limestone*.—The Utica consists of fine-grained, gray or bluish-gray limestone layers, from 2 to 5 inches thick, interbedded with equal thicknesses of shaly clay. At Clifton, on the Tennessee river, attempts were made before the war to burn it into a cement; it is, therefore, referred to by Professor Safford² as the hydraulic limestone. He estimates its thickness at Clifton as 70 feet down to low water, its base not being exposed at any point in the Tennessee river valley in western Tennessee.

¹ "The Cincinnati Anticline in Southern Kentucky," *Am. Geol.*, December, 1902.

² *Geology of Tennessee*, 1869.

The limestone is exposed also twelve miles eastward, three and one-half miles northwest of Waynesboro, near the home of W. D. Helton on Beech creek; here it is overlaid by the limestone forming the base of the Richmond group. It occurs off and on down Beech creek as far as its junction with Little Beech creek, and is exposed also along the road from Waynesboro to Clifton, a short distance west of the home of W. D. McAnally, near the crossing of Eagle creek, three miles east of Clifton.

The most southern exposure occurs about twenty miles southwest of Clifton, at the mill variously known as the Maddox, Welch, or Old Graham mill, located on Horse creek. Here only the upper fifteen feet of the limestone is exposed, overlaid by a few inches of clayey material belonging to the Richmond. The Utica is the only Ordovician rock exposed along Willoughby creek from its mouth at Lick Ford, for several miles up stream. It occurs along the lower parts of Indian and Hardin creeks. The most western outcrop is located on Miles creek, one mile south of Saltillo, at the site of an old mill, a quarter of a mile above the mouth of the creek.

The typical section occurs at Clifton, on the Tennessee river; however, since the name Clifton has already been applied by Professor Safford to the Silurian of Tennessee, the name *Saltillo* has been chosen.

The Saltillo limestone contains comparatively few species of fossils, and most of these are not abundant. The most widely distributed species is a variety of *Dalmanella emacerata*,¹ 20^{mm} in width, which is abundant at Clifton and on Beech creek, northwest of Waynesboro. There is also a smaller variety of *Dalmanella* at Clifton, with coarser plications, identified as *Dalmanella multisecta*.²

In addition to the *Dalmanellas* named, the following fossils have been found in the Saltillo limestone at Clifton. *Zygospira modesta* is very abundant in several layers near the top of the limestone. A globular sponge with acicular spicules is very abundant in one of the lower layers; it is probably a species of

¹ *Pal. New York*, Vol. VIII, Plate V c, Fig. 2.

² *Pal. Olivo*, Vol. I, Plate VIII, Fig. 1, a, b, c.

Hindia related to *Hindia gregaria*. In some layers a brachiopod, identified as *Leptobolus insignis*, is abundant and well preserved. This fossil occurs at Cincinnati only in the lower third of the Utica, and it is the presence of *Leptobolus insignis* and *Delmanella emacerata* in the Saltillo limestone which has led to its identification as equivalent to the Utica.

In the Wells creek basin, along the railroad southwest of Cumberland City, in northwestern Tennessee, a series of limestones interbedded with shaly clays occur which lithologically resemble the Saltillo limestone of southern Tennessee. A slight resemblance is shown also by that part of the Cape Girardeau limestone which is interbedded with shaly clay. The top of the Cape Girardeau limestone belongs to the Silurian. The fossils so far collected from the Ordovician part of the Cape Girardeau limestone indicate merely an age corresponding to the lower part of the Cincinnati group, but whether they are Utica or Lorraine cannot be determined with the evidence at hand. The Richmond group appears to occur in Jefferson, Warren, and Pike counties, in Missouri, judging from the presence of *Dinorthis subquadrata*, *Platystrophia acutilirata*, and *Strophomena planumbona*.¹ While Richmond group fossils are listed from localities farther south, along the Mississippi, nearer to Cape Girardeau, they are listed together with other fossils which are certainly not of Richmond age, suggesting a possibility of incorrect determination.

2. *The Warren limestone*.—If the occurrence of *Leptobolus insignis* is sufficient to refer the Saltillo limestone to the Utica, then the Lorraine has a very limited geographical extent in the Tennessee river valley. At Clifton, above the landing, the northeastern end of the outcrop of Lorraine has a thickness of three feet four inches. At the old cement mill at the southwestern end of town, its thickness is only a few inches. The Lorraine has not yet been detected elsewhere. This is rather surprising, since Mr. J. M. Nickles states that at Columbia, sixty miles east of Clifton, Mount Parnassus is a noted locality for Lorraine fos-

¹ *Missouri Geol. Surv.*, Vol. V, 1894; also SHUMARD, *Reports* for 1855-71, and SWALLOW, *Reports* 1 and 2, 1855.

sils,¹ and the section there is considerable.² The Lorraine at Clifton consists of gray or bluish-gray, coarse-grained limestone which may be readily distinguished from the Richmond limestone immediately above by the presence of considerable chert. It is very fossiliferous, but the fossils must be broken out of the rock and do not form good cabinet specimens.

The most common and at the same time most characteristic fossil is *Dinorthis retrorsa*. In Ohio and Indiana this fossil has a very limited vertical range, being confined to a bed, rarely exceeding one or two feet in thickness, near the top of the Lorraine. This bed is included in the subdivision to which Mr. Nickles gave the name "Warren bed." The Lorraine bed at Clifton, here described, is therefore identified as the Warren limestone.

Another rather abundant species is a form of *Rhynchotrema dentatum* which differs from that found in the Richmond in the possession of three distinct plications and one indistinct plication on either side of the dorsal fold instead of four distinct and one or two indistinct plications, as in the Richmond group. In consequence, the plications appear more angular. This form occurs also at the top of the Lorraine half a mile southwest of Howards mill, in Montgomery county, Ky.

Leptæna rhomboidalis is fairly common. This species occurs associated with *Dinorthis retrorsa* also at the base of the Morris Hill section, in the hollow directly west of the mouth of Cæsar's creek, in Warren county, O.

A *Dalmanella*, belonging to the group of *D. testudinaria*, is very common. The dorsal valve is flat and has a distinct mesial depression, extending from the beak to the anterior margin. The plications bifurcate two or three times. It resembles most the form identified in Indiana and Ohio as *Dalmanella jugosa*³, and differs chiefly in having a flat dorsal valve and coarser plications. The typical forms of *Dalmanella jugosa*, on the contrary, have a moderately convex dorsal valve. Both forms are common at the

¹ *The Geology of Cincinnati*, p. 74.

² SAFFORD, *The Geology of Tennessee*, p. 265.

³ HARPER AND BASSLER, 1896, *Catalogue of Fossils of Cincinnati*, p. 16; NICKLES, 1902, *Geology of Cincinnati*, p. 92.

base of the Richmond in Indiana, Ohio, and northeastern Kentucky, and at some of the more northern localities they occur also at the top of the Lorraine, but usually in much smaller numbers. In fact, the base of the Richmond in Indiana and Ohio and northeastern Kentucky is usually indicated by the presence of several thick layers of limestone, often wave-marked, and a first appearance or sudden increase of *Dalmanella jugosa* and of its related form.

A large form of *Cyclonema bilix*, having a vertical height of fully one inch, is not rare. It appears most closely related to the typical forms as illustrated by Ulrich.¹

Helcionopsis striata is represented by a single specimen, showing the characteristic markings on the surface. The specimen is, however, only 14^{mm} long. The type specimen² was found in "the upper beds of the Cincinnati formation, Marion county, Ky." Since the thickness of the Richmond formation in this county does not exceed 35 feet, it is very probable that the type specimen also came from the upper part of the Lorraine.

Columnaria stellata (*Columnaria alveolata* as identified by Nicholson)³ is represented by a single specimen, showing alternately larger and smaller septa, the larger extending nearly or quite to the center of the visceral chamber.

3. *Richmond limestone*.—Immediately above the Warren bed, at Clifton, there are nineteen feet of Richmond limestone. The lower and middle part is coarse-grained, often cross-bedded, has a lighter color, and contains very few fossils. The upper part is more clayey and finer grained, forming a transition to the Richmond shaly clays immediately above. The top of the coarse-grained limestone and the clayey limestone above contains a greater number of fossils, but these are usually imbedded in the rock and cannot be secured without a considerable expenditure of time.

The identification of this limestone as Richmond is based upon the presence of a single specimen of *Rhynchotrema capax*

¹ *Minnesota Geol. Surv.*, Vol. III, Part II, Pl. LXXVII, Fig. 35.

² *Ibid.*, p. 827.

³ *Pal. Province of Ontario*, 1875; also, *Paleozoic Tabulate Corals*, 1879.

at the base of the limestone near the old abandoned cement mill at the southwestern end of the town, and of a specimen of *Strophomena planodorsata*.

The form of *Rhynchotrema capax* found at the base of this limestone is much more abundant at the top of the limestone and in the overlying Richmond clay; it is most numerous near the top of the clay, one specimen being found even included in the Clinton rock, half an inch above its base. This form differs from the *Rhynchotrema capax* of the Richmond of Ohio, Indiana, and Kentucky, chiefly in size. It is smaller; the largest and most obese specimen so far found does not exceed 20^{mm} in thickness and 16^{mm} in width. It is also more narrow, and while the typical specimens from the Richmond of Indiana and Ohio have five distinct plications on either side of the fold of the dorsal valve, the Tennessee specimens here described have seven, and occasionally even eight, plications. The internal markings are the same. It may be called *Rhynchotrema capax manniensis*.

The dorsal valve of *Strophomena planodorsata*¹ is slightly concave over an area exceeding half the length of the shell, and has a flat appearance over an area equaling two-thirds of its length. The striæ are even finer than those figured by Winchell and Schuchert. One specimen occurred nine and one-half feet above the base of the Richmond limestone and others were found near the top. *Rafinesquina alternata*, *Plectambonites sericeus*, and *Hebertella sinuata* also occur.

The most interesting fossil is a species of *Lingulops* belonging to the subgenus typified by *Lingulops granti*,² a Silurian species from Hamilton, Ontario. It agrees in having the muscular area of the pedicle valve developed into a well-defined platform the anterior edge of which is not prolonged into a septum. Its length is 6^{mm}. The median impression between the central muscular scars is relatively more narrow; the platform does not extend as far toward the beak; the position of the pedicle may be recognized. The name *Lingulops cliftonensis* is suggested.

¹ *Minnesota Geol. Surv.*, Vol. III, Part I, p. 393.

² *Pal. New York*, Vol. VIII, Part I, Pl. IV K, Fig. 15.

Richmond limestone is also exposed a short distance up stream from the home of W. D. Helton, on Beech creek, northwest of Waynesboro. It is seven feet thick, is rather coarse-grained, varies in color from light brown to bluish-gray, and is fossiliferous.

Among these fossils are the forms identified as *Strophomena planodorsata*; *Rafinesquina alternata*; a large *Cyclonema bilix* similar in form to that found in the Warren bed at Clifton, but having a vertical height of 36^{mm}; and a form of *Dalmanella* with a moderately convex dorsal valve, evidently related to *Delmanella jugosa* as found in the Richmond of Ohio and Indiana.

4. *The Mannie shale, or shaly clay.*—Immediately above the Richmond limestone, at Clifton, there is 15½ feet of brownish and bluish shaly Richmond clay. It contains *Rafinesquina alternata*, *Plectambonites sericeus*, and *Rhynchotrema capax manniensis*. A single specimen of *Dinorthis subquadrata* was found imbedded in the Clinton, one inch above its base. The characteristic muscular area is exposed. The plications are somewhat finer and more numerous than in the Richmond of Ohio, Indiana, and Kentucky. The presence of *Rhynchotrema capax manniensis* in the base of the Clinton has been noted already. They are simply Richmond specimens loosened from the clay beneath and mingled by the wash of Clinton seas with living Clinton forms.

Northwest of Waynesboro, on Beech creek, near the home of W. D. Helton, the 20 to 25 feet of section between the Richmond limestone and the Clinton, not exposed, probably consist of Richmond clay.

The upper part of the Richmond clay is seen beneath the Clinton just north of the west end of the railroad bridge across the Buffalo river northwest of Riverside, a mile and a half north of Mannie or Allens creek. Six feet is exposed; unfossiliferous.

About three-quarters of a mile west of Riverside, west of Mr. Howard's home on the road to Flat Woods, east of the mouth of Trace creek, the Richmond shaly clay is exposed on the north side of the road. The exposure is 33½ feet thick; the base of clay is not seen. The lower 11 feet of the section consists of fossiliferous weathered clayey rock; the fossils are found chiefly

in the upper half of this rock. Above this are 8 feet of weathered clayey limestone in which fossils are very few. This is overlaid by $14\frac{1}{2}$ feet of clay, apparently unfossiliferous at this locality. The name "Mannie shale" is suggested for the shaly clay which forms the upper part of the Richmond in western Tennessee.

The most common fossil is *Rhynchotrema capax manniensis*. A form identified as *Dalmanella jugosa* is also abundant. A single pedicle valve of *Strophomena rugosa* (*Strophomena planumbona* of the Ohio Survey) was found, exposing the interior, also a single dorsal valve of the form identified as *Strophomena planodorsata*. *Platystrophia cypha* is not rare. The largest specimen is 37^{mm} wide, the postero-lateral angles equal about 65°, the fold of the brachial valve is occupied by four plications, and on each side of the fold there are about twelve lateral plications. In Ohio and Indiana this form extends from the upper part of the Lorraine to the top of the Richmond. *Platystrophia acutilirata* may be regarded as the most aberrant variation. One specimen of *Platystrophia crassa* was found, and one of *Plectambonites sericeus*. The most interesting specimen, however, is a single specimen of *Lingulasma*[†] preserving the characteristic ornamentation of the surface, and showing enough of the interior structure to suggest its generic relationship, but it is too poorly preserved to warrant a more specific description. It is about half as large as the species hitherto described.

North of Clifton, both the Richmond limestone and the Richmond clay may be traced for a considerable distance along the Tennessee river. Southward, the Richmond thins out rapidly. At the Maddox mill, on Horse creek, a few inches of clayey material intervenes between the top of the Saltillo limestone and the base of the Clinton. In this clay was found a specimen which is identical with *Helcionopsis striata* in form, but it does not preserve the surface striæ, being evidently an internal cast. Its length is 21 mm. There is also a single specimen of *Rhynchotrema capax manniensis*, and of *Leptaena rhomboidalis*. Possibly

[†] *Pal. New York*, Vol. VIII, Part I, Pl. II; also, *Minnesota Geol. Surv.*, Vol. III, Part I, Pl. XXX.

this clay represents residual material both from the Warren limestone and from the Richmond beds. It is impossible to determine from the evidence at hand. There is no doubt, however, of the thinning out both of the Warren bed and of the two members of the Richmond group southwestward, on approaching the southern part of Hardin county.

C. THE CINCINNATI GROUP BETWEEN THE TENNESSEE RIVER VALLEY AND THE CENTRAL BASIN.

It should be noticed in this connection that the Clinton also thins out southwestward. At Newsom it is 30 feet thick. At Centreville 20 feet of Clinton is exposed and the base is not seen; it may therefore approach 30 feet in thickness. However, at Riverside, north of the railroad bridge, the thickness of the Clinton is only 5 feet 9 inches, and it consists of strongly cross-bedded limestone. At Dunkirk, about three miles below Clifton, its thickness is 3 feet 9 inches. At Clifton it does not exceed one foot. South of Clifton it has not been recognized. If it occurs at Maddox mill, it cannot be distinguished from the Osgood limestone at that point.

5. *The Leipers creek limestone*.—About thirty-two miles northeast of Riverside, along Leipers creek, Richmond limestone is well exposed. It occurs two and one-fourth miles south of Fly, near the top of the bluff north of the home of J. M. Gardner; also a quarter of a mile north of Fly, in the bed of the creek, and for some distance along the branch of Leipers creek which passes the homes of Carol Litton and Tom Fox, near the old *Oil Well*. The limestone varies from 6 to 9 feet in thickness, is coarse-grained, often crinoidal, and frequently has a salmon-brown color. It contains a species of *Strophomena* regarded by Mr. Charles Schuchert as closely related to *Strophomena Wisconsinensis*, as far as could be determined without seeing the interiors; also forms resembling *Strophomena rugosa*, and the form identified as *Strophomena planodorsata*. To this Richmond limestone the name *Leipers creek limestone*¹ has been given.

Overlying the limestone is a clay shale which corresponds

¹"Silurian and Devonian Limestones of Tennessee and Kentucky," *Bull. Geol. Soc. Am.*, Vol. XII (1901).

stratigraphically with the *Mannie shale*. Above the limestone at the J. M. Gardner locality it contains *Rhynchotrema capax manniensis*. A quarter of a mile northeast of Fly, beyond the home of R. S. Elam, the bed is 6 feet thick, and contains about 1 foot of poor shaly limestone 1 foot above the base. In the shale and in the interbedded shaly limestone are found *Orthis proavita*; *Dinorthis subquadrata*; a form of *Hebertella insculpta* with finer striæ, and with a deeper median depression in the dorsal valve than is usual in Ohio specimens; a typical specimen of *Platystrophia acutilirata*; typical specimens of *Strophomena neglecta*; and specimens of *Rafinesquina* which belong to the group of *Rafinesquina minnesotensis inquassa*, showing distinctly the median septum and less distinctly the lateral septa characteristic of the dorsal valve. A very large form of *Hebertella occidentalis*, often 50^{mm} wide, occurs both at the Elam locality and in the 4 feet of clay which overlies the Leipers creek limestone north of the home of Tom Fox. At some localities the clay is absent.

The Leipers creek bed crops out again ten miles north of the Tom Fox locality, along the valley of the South Harpeth creek. It is still a coarse-grained limestone, usually crinoidal, but its color is bluish, with small brownish spots. Its thickness is also about the same, varying from 5 to 9 feet. It occurs in the creek bed south of Fernvale; one mile southeast of Fernvale on the road to Leipers Fork post-office, at the home of Mrs. Annie Inman; at the schoolhouse two miles north of Fernvale; north of the mouth of the branch entering South Harpeth creek a quarter of a mile south of the home of Jim Linton, Sr.; and apparently also back of the home of W. M. Forehand, half a mile west of Tank.

At the first two localities the limestone is directly overlaid by the Chattanooga black shale (Devonian). At the other localities it is overlaid by Richmond clayey shale, equivalent to the Mannie shale. The thickness of the Richmond shale does not exceed 10 feet at any locality visited.

At the Inman locality the limestone contains *Dinorthis subquadrata*, and a species of *Strophomena*. At the schoolhouse

north of Fernvale, the limestone contains *Orthis proavita*, *Dinorthis subquadrata*, *Hebertella insculpta*, and *Strophomena rugosa subtenta*. The clay shale immediately above the limestone appears to be unfossiliferous.

Richmond limestone is exposed three miles north of the Forehand locality, along the banks of the Harpeth river, at Newsom. It is a coarse-grained limestone, varying from bluish to light brown, and at least 10 feet thick. Its age is indicated by the presence of a single ventral valve of *Dinorthis subquadrata*, showing the muscular scar. The unexposed part of the section, between the Richmond limestone and the base of the Clinton, may be occupied by Richmond clay.

The most northern exposure of Richmond limestone, equivalent stratigraphically to the Leipers creek limestone, occurs at Baker, twenty-three miles northeast of Newsom. Here it is four feet thick, is a coarse-grained limestone, and contains *Strophomena Wisconsinensis*, or at least a form closely resembling this species in general appearance. No Richmond shale was noticed.

6. *Swan Creek Limestone*.—At Newsom the coarse-grained limestone is underlaid by clayey rock which contains numerous specimens of the form identified in Ohio and Indiana as *Dalmanella jugosa*; it there extends from the upper beds of the Lorraine through the lower part of the Richmond; the dorsal valve is slightly convex. Four typical specimens of *Rhynchotrema dentatum* were found. The presence of a single specimen of *Platystrophia lynx* with a short hinge line suggests the Lorraine age of this rock. The thickness of the clayey rock is not known, only a few feet being exposed above the level of the river.

Platystrophia lynx was also noted below the Leipers creek bed at the Inman locality, a mile southeast of Fernvale.

At the J. M. Gardner locality the Leipers creek limestone is underlaid by a considerable thickness of more or less cross-bedded limestone containing very few fossils, and this in turn is underlaid by clayey limestones in which fossils are numerous.

All along the Swan Creek valley, cross-bedded Ordovician limestone containing very few fossils is very well exposed. At the spring, a quarter of a mile south of Swan Bluff, it measures

about fifty-six feet, and is underlaid by the richly fossiliferous, more clayey layers, containing *Platystrophia lynx*. It also occurs up the valley along the railroad south of Centreville. To this cross-bedded, nearly unfossiliferous, Ordovician limestone the name "Swan creek limestone" is here given. Judging from the exposures at Swan Bluff and at the J. M. Gardner locality, it is of Lorraine age, probably below the *Dinorthis retrorsa* horizon.

At the quarry, a sixth of a mile up the hollow, east of the home of J. D. Dean, this cross-bedded limestone has disintegrated into a brownish mass which has been quarried as brown phosphate. The cross-bedded limestone which occurs at Clifton, and which has there been identified as Richmond, has also disintegrated into a brown phosphate rock immediately below the old cement mill at the southwestern end of the town. It appears, therefore, that waters sufficiently turbulent to produce cross-bedding were present during the deposition of both the upper Lorraine and of the lower part of the Richmond in western Tennessee. The Leipers creek bed is often cross-bedded, as well as coarse-grained. Between the cross-bedded Swan creek limestone and the coarse-grained Leipers creek limestone, a thin section of clayey rock, apparently of Lorraine age, intervenes in places. This is probably the position of the clayey rock at the base of the section at Newsom.

D. CONCLUSIONS.

According to the preceding observations, the Ordovician exposures in the valleys of the Tennessee river, the Buffalo river, Swan creek, Leipers creek, and South Harpeth creek suggest the following lithologic succession, in descending order:

Cincinnati Group.	Richmond	<ul style="list-style-type: none"> Mannie shale. Leipers creek limestone. Warren limestone; clay rock at Newsom. Swan creek limestone.
	Lorraine	<ul style="list-style-type: none"> Richly fossiliferous Lorraine limestone in the eastern part of the area studied, containing <i>Platystrophia lynx</i>.
	Utica	<ul style="list-style-type: none"> Saltillo limestone.

The Lorraine appears to become thinner west of the Cincinnati anticline, so as to be represented by thinner sections or so

as to be entirely absent along the Mississippi in Missouri and adjacent Illinois, in the Wells creek basin in northern Tennessee, and along the Tennessee river in southern Tennessee. The Richmond also appears to become thinner west of the northern half of the Cincinnati anticline. It becomes thinner also southward along the flanks of the anticline. In some parts of Tennessee it is entirely absent along the western flank of the anticline. West of the southern half of the anticline, in Tennessee, the thickness of the Richmond appears to vary irregularly. It has not been detected in the Wells creek basin. A thicker clay section than usual is seen west of Riverside. Both the limestone and clay are thicker at Clifton than at most points nearer the anticline. In the southern part of Hardin county, the Richmond thins out to a few inches. If the identification of the Saltillo limestone as lower Utica, and of the overlying limestone at Clifton as the Warren bed, is correct, a very considerable interval of erosion occurred during the middle of the Cincinnati age in western Tennessee.

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